



# Vulnerability to water shortages in the 21st Century's arid and semi-arid American West

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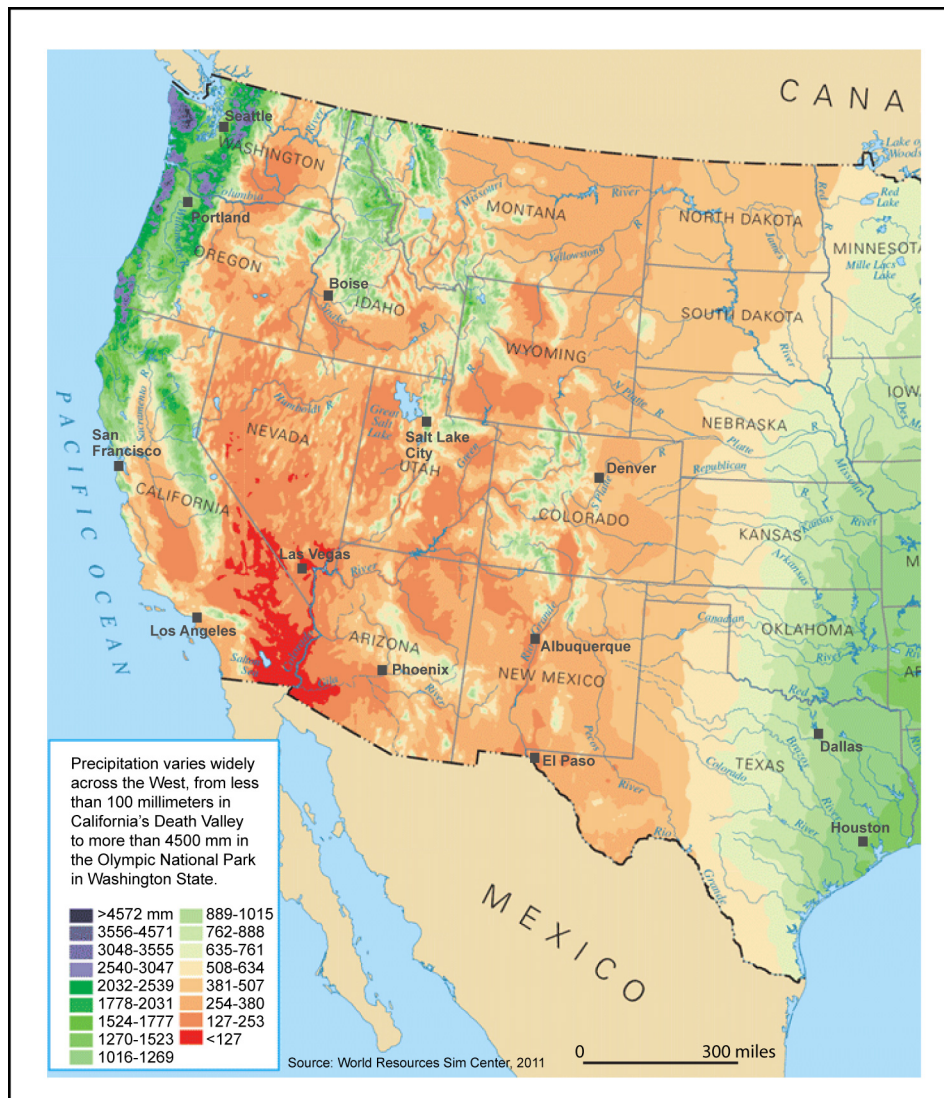
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Nicolas Barbier

# Vulnerability to water shortages in the 21<sup>st</sup> Century's arid and semi-arid American West

## Introduction

- <sup>1</sup> Most of the area within the eleven States that comprise the American West<sup>1</sup> is either arid (average annual precipitation under 250 millimeters) or semi-arid (250 to 500 millimeters). Some of the most arid areas are located near the border between Arizona, California and Nevada, in southeastern Utah or southwestern Wyoming. By contrast, a smaller part of the American West receives much more rainfall: under the maritime influence of the Pacific Ocean, the western portions of Oregon and Washington as well as northern California generally receive an average annual rainfall that exceeds 800 millimeters. Records even go beyond 4,000 millimeters in the mountain ranges (Cascade Range) of northwestern Washington. The air descending east of the Coast Ranges rapidly dries and warms up, thus creating striking climatic and landscape contrasts. Others pockets of high humidity can be found in the Rocky Mountains. They are larger in the north (northern Idaho, western Montana, northeastern Wyoming) than in the south (fractions of central Arizona and Colorado, northeastern Utah, northern New Mexico) (Jackson 2003, 59-68; Riebsame 1997, 80-81; Taylor 2011).

**Figure 1 - Average annual rainfall**

Source: World Resources Sim Center, 2011

- 2 The size of areas receiving little rainfall constitutes a growing difficulty in water resource management. Managers have been faced with three problems: the colossal water consumption of irrigated agriculture (USGS 2009, 7); moderate or high population growth in most of the West for about twenty-five years (Infoplease, U.S. Census Bureau 2013); the impacts of global warming (Powell 2008, 179-181). At the federal, State and local levels, elected officials, governmental agencies, and courts are confronted with a wide-ranging economic and environmental concern: how can we prompt the participants in irrigated agriculture to change farm practices so that they significantly reduce water consumption? Under what rules, where and to what extent? In 2007, irrigated agriculture generated a large part of \$72 billion of agricultural revenues in the West (U.S. Census Bureau 2009, 532). This amount did not include revenues from the whole agri-food sector (induced revenues from the industries dependent upon agricultural products). The water needs of industries (cooling systems) and hydropower systems – locally important – are also put in jeopardy (e.g., dams in Arizona or southern California that provide electricity to millions of people) (USGS 2009, 7, 38). Elected officials, governmental agencies and courts remain generally reluctant to upset people's routine for two main reasons: it is difficult for them to adapt the existing economic, legal and political systems to climatic fluctuations; for the time being in most of the West, there is no risk of water shortages that requires very rapid and broad changes in the dominant agricultural practices or the lifestyle of most of the population. This relative comfort may soon change. In the arid and semi-arid West, the current structural vulnerability to water shortages risks turning into a major



functional disruption by 2050. If appropriate measures to save water are not taken during the forthcoming decades, an increasing number of farmers may have to stop their activity, urban growth may have to be drastically limited and lots of rivers may either dry up or turn into intermittent streams. This type of evolution could hurt the regional economy while causing widespread environmental degradation. Conflicts between water users could worsen. Within a generation, the current risk of water shortages could lead to a water crisis that would require millions of westerners to transform their relationship with water. By approaching vulnerability as “a measure of the extent to which a geographical area is likely to be disrupted, on account of its nature, location” and human intervention, “by the impact of a particular hazard” (OECD 2001),<sup>2</sup> we estimate the probability of shortages due to one or several phenomena: drought, global warming, and the management of water resources. In the American West, vulnerability to water shortages means that human activities, population growth and river flows may be impaired because of one or several of these phenomena. Vulnerability to water shortages is further understood as an assessment of the extent of the economic, social and environmental damages potentially caused by shortages. Based on this factual and conceptual background, this study hinges on three main questions. What are the characteristics of water resource management in the West? An explanation of the key legal concept of water rights as well as the presentation of the historical background of the management will help answer this question. What are the causes and consequences of the sectoral and spatial distribution of the vulnerability to water shortages? The areas most exposed to vulnerability, its main factors, geographic variations and regional particularities will be specified. What are the solutions, applied, considered or conceivable? Some agricultural, legal and societal solutions will be presented.

## **I/ Explanation of the growing regional vulnerability to water shortages**

### **1/ Methodology based on multiple sources and field work**

3 As a visiting scholar and PhD student at the University of Idaho for three years, my research included the Snake River Basin Adjudication Agreement. This 2005 agreement was signed by the federal government, the State of Idaho and the Nez Perce Indian Tribe to bring an end to thousands of conflicting water rights in Idaho. In order to study this issue related to the vulnerability to water shortages in Idaho, two simultaneous methods were applied: the synthesis of legal and governmental documents, scientific articles and book chapters; the use of excerpts from filmed interviews with people directly involved in the conflicts and agreement (e.g., the director of the Alliance that opposed Nez Perce water right claims; the director of the Idaho Water Users Association; the chairman of the Nez Perce Tribe, etc.). Since I defended my PhD dissertation (Barbier 2012), I have extended the geographic scope of my study on the management of water resources to the entire American West while focusing on its vulnerability to water shortages. This emphasis requires the use and synthesis of extracts from a large number of other legal and governmental documents, scientific reports, articles and book chapters as well as press releases. The projected impacts of climate change in the context of population growth and persisting irrigated agriculture on vast areas has to be examined. The West is confronted with vulnerability to water shortages in varying degrees from one sub-region to the next. This variability should be identified. In order to be as accurate as possible in the analyses, several experts from universities and governmental agencies were contacted via emails (see “Information provided by emails” at the end of the article). The first step of this postdoctoral work consisted in writing drafts of the different parts of the study. After this, the conclusion and introduction could be written up and the arguments refined. The building of the final plan of this article was the last phase.

4 Because the management of water resources in the American West is based on water rights, the beginning of a study on the vulnerability to water shortages should include a definition of this concept.

## 2/ Historical and legal background about water resources management in the West

- 5 A water right means a certain amount of water withdrawn from a particular location, made available for use in a specific place for defined periods of time (Hutchins 2004, 13-14, 23-24; Wilkinson *et al.* 1993). According to U.S. law, any use of a water right must be “beneficial” (e.g., industrial, agricultural, municipal, mining, hydroelectric and domestic) and “reasonable” given the needs of society. Otherwise, a court has authority to deprive a water-right holder from one’s right (Castle 2008; Freyfogle 2003, 231-234).
- 6 “State law governs the allocation and administration of water rights unless State law interferes with congressional directives” (Amos 2006, 1240). A ruling of the U.S. Supreme Court, an act of Congress or an interstate agreement (such as the Colorado River Compact between seven western States) can bring an end to conflicts about water rights in a river or river basin that extend over several States (Sherk 2000). In the eleven western States, State law specifies that water resources within State boundaries are either public property (Arizona, Nevada, New Mexico, Oregon, Utah, Washington) or the property of the State and its population (California, Colorado, Idaho, Montana, Wyoming) (Hutchins 2004, 6). States manage and control groundwater and surface water within their respective territories for the use and benefit of their citizens (Cameron 2009, 20). State departments (e.g., Idaho Department of Water Resources, Colorado Division of Water Resources) issue permits to use water (a water right) for water right applicants. A water right is attached to the land and transferred to a new owner when the property is sold (Hutchins 2004; Wilkinson *et al.* 1993). Public agencies (e.g., water districts, irrigation districts or ground water districts) or private entities (canal or ditch companies) allocate water on the ground in compliance with State law and policies.
- 7 As the West was settled, water rights were allocated according to the prior-appropriation doctrine: the first settler holds a right which preempts those of subsequent migrants. For instance, a water right allocated in 1900 preempts another one granted in 1933. Under this system, the most recent water rights (junior water rights) in a given area can be restricted during periods of shortage, whereas older rights would be maintained. So these senior water rights are more valuable. However, in times of drought, urban water supply (domestic and industry) is the top priority even if agriculture suffers (Wilhite 6/4/2013, email). During drought conditions, holders of senior water rights frequently lease their rights to holders of junior rights.
- 8 The system of prior-appropriation doctrine was implemented in the 19<sup>th</sup> century. It allowed farmers and mining contractors to use large volumes of water in places sometimes located at a considerable distance from water withdrawal sites. Between the 1870s and 1960s, an extensive network of canals, ditches, aqueducts and a multitude of dams were built (Libecap 2010, 60). During the 1930s, the New Deal freed up substantial federal funds for water development projects to help stimulate the economy after the Great Depression. In areas such as the southwestern portion of the American West, it took a few years to build some of the largest pieces of infrastructure in order to meet the desires of most regional stakeholders. Thus, the Imperial Dam, located on the lower Colorado River along the California-Arizona border, was completed in 1938. Four years later, the 132 kilometer long All-American Canal connected this river (Imperial Dam) to the Imperial Valley (southeastern California) while supplying several local cities with water. This valley is crossed by a lot of irrigation ditches. Meanwhile, in 1939, the 389-kilometer long Colorado River Aqueduct connected Parker Dam (1938) on the same Colorado River to Lake Mathews east of Los Angeles (Colorado River Water Users Association 2014).
- The first goal of this infrastructure was agricultural and urban development.

## 3/ Irrigated agriculture: the dominant factor of vulnerability compounded by others

- 9 Intensive agriculture based on massive consumption of water is maintained on immense arid and semi-arid areas. The water interests of farmers have been protected by political leaders in the West. As Elwood Mead (1858-1936) argues, farmers got into the habit of wasting water.

Lake Mead on the Colorado River was named after this former director of the U.S. Bureau of Reclamation (BOR):<sup>3</sup>

When irrigation first began, [...] irrigators had all they wanted, and because it cost nothing and they were free to take it as they pleased they failed to realize its coming scarcity and importance. [...] Ditches diverted more water than was used. Their owners claimed more than they could divert, while decrees gave appropriators titles to more water than ditches could carry and many times what the highest flood could supply. Little was known of the quantity of water needed to irrigate an acre of land, and in the absence of such information the ignorance and greed of the speculative appropriator had its opportunity (quoted in: Wilkinson *et al.* 1993, 131).

- 10 Although irrigation methods have evolved, irrigated lands have expanded considerably and their water consumption has become gigantic. The BOR, a federal agency under the U.S. Department of the Interior (USDOI), has participated in this development. It currently manages 600 federal dams and their reservoirs. It sells or leases water to 140,000 farmers who represent one out of five western farmers. Together, they farm about 40,000 km<sup>2</sup> (U.S. Bureau of Reclamation 2013). In 2005,<sup>4</sup> more than 102,000 km<sup>2</sup> (10.2 million hectares) were irrigated within the eleven western States including 37,000 km<sup>2</sup> in California, 14,000 in Idaho and 12,000 in Colorado (USGS 2009, 24).<sup>5</sup> The part of agriculture in total water withdrawals dominates all other water uses. In 2005, in nine States out of eleven, irrigation used between 74 percent (California) and 95 percent (Montana) of the total water withdrawals (63 percent in Nevada and Washington). It greatly exceeds the percentage of public supply (for domestic, commercial, industrial and public services purposes)<sup>6</sup> which comes second in most States (e.g., 28 percent in Nevada, 19 percent in Arizona, 9 percent in New Mexico, 6 percent in Colorado). Aquaculture is second in Idaho with 13 percent and Oregon with 9 percent. In most States, it should be noted that more water is withdrawn for public supply than thermoelectric power (e.g., 8 percent in Washington [first rank in the West], 1 percent in Colorado and Montana). The latter “is used in generating electricity with steam-driven turbine generators” (USGS 2009, 7, 24). These different water uses coexist within a water market under pressure that members of the agricultural sector tend to dominate in vast areas.
- 11 Water-right holders from the agricultural sector (for instance farmers or irrigation districts) normally set a low median and mean price when they sell or lease their rights to others working in the same sector. On the contrary, they generally set a high price for urban buyers or lessees. Between 1987 and 2008 in the American West<sup>7</sup>, the median price for agriculture-to-urban water leases<sup>8</sup> was 6 cents per cubic meter (\$74 per acre-foot)<sup>9</sup> against 1.5 cent for agriculture-to-agriculture<sup>10</sup> leases. The median price for agriculture-to-urban sales (24 cents) was twice higher than that for agriculture-to-agriculture sales (12 cents). When their activity does not suffer from it, members of the agricultural sectors profit from the lucrative opportunity that a sale or lease of water rights to urban entities represents. As a result of urban growth, the number of these transactions has gone up since the 1980s. In the 2000s, their number was higher than transactions within the agricultural sector (twice higher in 2008 and 2009; seven times in 2003 when a drought affected much of the West). The number of agriculture-to-environmental transactions (in order to augment instream flows for example) was comparable to the ones within the agricultural sector. Higher costs of water diversions toward cities only account for a slim fraction of price discrepancies between agriculture-to-agriculture transactions and agriculture-to-urban transactions. In many cases, urban buyers or lessees are municipal water districts or city water departments (Libecap<sup>11</sup> 2010, 66-68).
- 12 In order to secure their future water supply, municipalities tend to purchase parcels of land and water rights attached to them (Wilhite 6/4/2013, email). From 2000 to 2010, a part of the population growth in the American West (from +10 percent in Montana to +35 percent in Nevada)<sup>12</sup> concentrated in metropolitan areas: +22 percent in Albuquerque, New Mexico; +33 percent in Boise (southern Idaho); +42 percent in Las Vegas, Nevada... (U.S. Census Bureau, 2013). There are regional disparities, but in general population growth in the West is the result of two principal assets: more job opportunities (people commonly migrate *before* finding a job); a better quality of life (easy access to wilderness areas, national parks and other protected public lands) (Travis 2007).

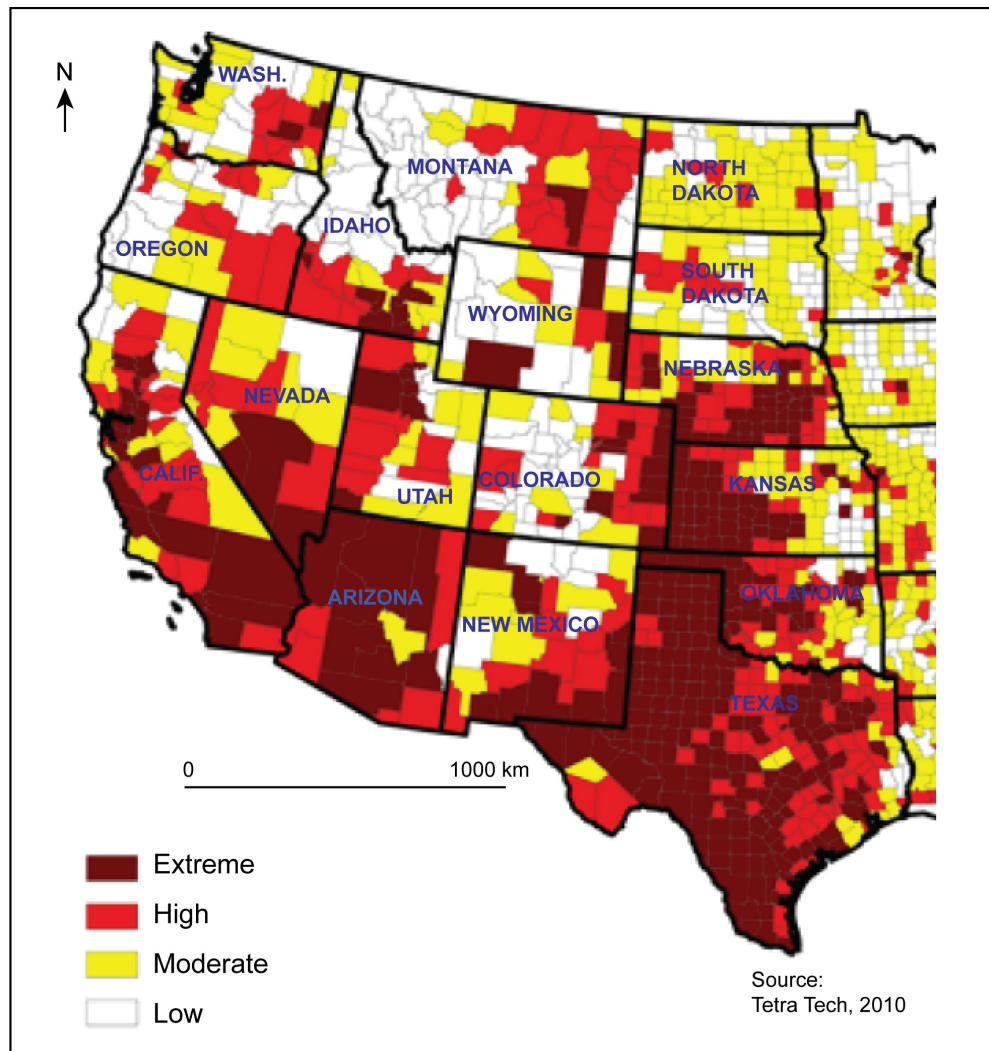
- 13 Today, this quality of life is at stake in vast tracts of the Colorado River Basin. 20,000 km<sup>2</sup> of agricultural lands and 30 million people depend on water from the Colorado River in seven States (Arizona, California, Colorado, Nevada, New Mexico, Utah and Wyoming). The construction of dams, canals, levees and waterways and the drainage of wetlands have transformed countless ecosystems. This development resulted in the “radical simplification of the geomorphology of the Colorado River and the loss of much of its original diverse habitat and many associated bird and fish species” (Graf 2001, 12). This environmental degradation was associated with the overallocation of the river’s waters. Overallocation means that there was more water allocated than the river could supply. This mistake dates back to 1922 when calculation was based on the highest river flows ever recorded. The effects of recent droughts combined with rising water consumption (due to population growth) were worsened because of this overallocation. When all of the overallocated water is used, river flows and water levels in reservoirs dangerously decline (Mays 2006, 79; Stratfor Global Intelligence 2013).
- 14 This phenomenon should worsen with global warming, as demonstrated by a recent study.

#### 4/ Recent scientific assessment of the regional vulnerability to water shortages

- 15 A part of a 2010 study focused on the probable impacts of global warming on water resources. Upon the request of the Natural Resources Defense Council (an environmental group with 1.4 million members and 350 expert contributors), this study was carried out by Tetra Tech (scientific services) in cooperation with the universities of Washington (Seattle), Santa Clara (California) and the Nature Conservancy (another popular environmental group) (Tetra Tech 2010; NRDC 2013). It is about the probability of water shortages in 2050 on a county and State scale. Three main categories of water uses and another parameter were taken into account in order to calculate this probability:
- Agricultural, commercial, industrial and mining uses, assuming that their withdrawals of water will be the same in 2050 as in 2005.
  - Public uses<sup>13</sup> calculated on the basis of a per capita water use<sup>14</sup> in 2005 and assuming that the demographic change (for counties) until 2050 will be at the same rate as from 2000 to 2008.
  - Uses for electricity production and cooling systems calculated by federal personnel.
  - A forecast for climate change based on a synthesis of the results of sixteen forecast models developed by public institutions (mostly universities) (Tetra Tech 2010).
- 16 According to this study, by 2050, the vast majority of the counties in Arizona, southeastern New Mexico, southern California and Nevada, western Utah, eastern Montana, southwestern Idaho and the far east of Colorado will face a high or extreme risk of water shortages and measures to restrict water uses (Figure 2). The arid or semi-arid parts of southeastern Oregon and Washington will be affected too. The vulnerability to water shortages of these sub-regions tends to increase when at least two of the five following determinants of risk are met. First, “the ratio of groundwater withdrawal to total water withdrawal is greater than 25 percent (greater withdrawals may be indicative of unsustainable use of aquifers)”. Second, the susceptibility to drought rises. Third, the percentage of annual available precipitation (AAP) that is used is greater than 25 percent (AAP = sum of monthly available precipitation [monthly available precipitation = monthly precipitation *minus* monthly potential evapotranspiration]). Fourth, “the increase of total freshwater withdrawal between 2000 and 2050 is more than 20 percent”. Fifth, and finally, there is an “increased need for the storage of water” (Tetra Tech 2010).
- 17 Irrigated agriculture is expected to fuel much of these determinants of risk. Cultivated plants need more water when summer temperatures increase and the growing season gets longer. This need adds to the vulnerability to water shortages in a large part of the West where summer droughts should dominate (National Public Radio 2013). In arid and semi-arid regions, some farmers already have difficulties in irrigating a part of their lands because of periodic drought. In these places, the rising need of plants for water may force them to give up more farmland. Other areas fare better like northern Idaho, western Montana, the southern Oregon coast and northwestern Wyoming: they should experience increasing precipitation and only slightly

higher temperatures. So these areas should not be affected by significant water shortages in 2050 (Tetra Tech 2010).

**Figure 2- Risk of water shortages in 2050**

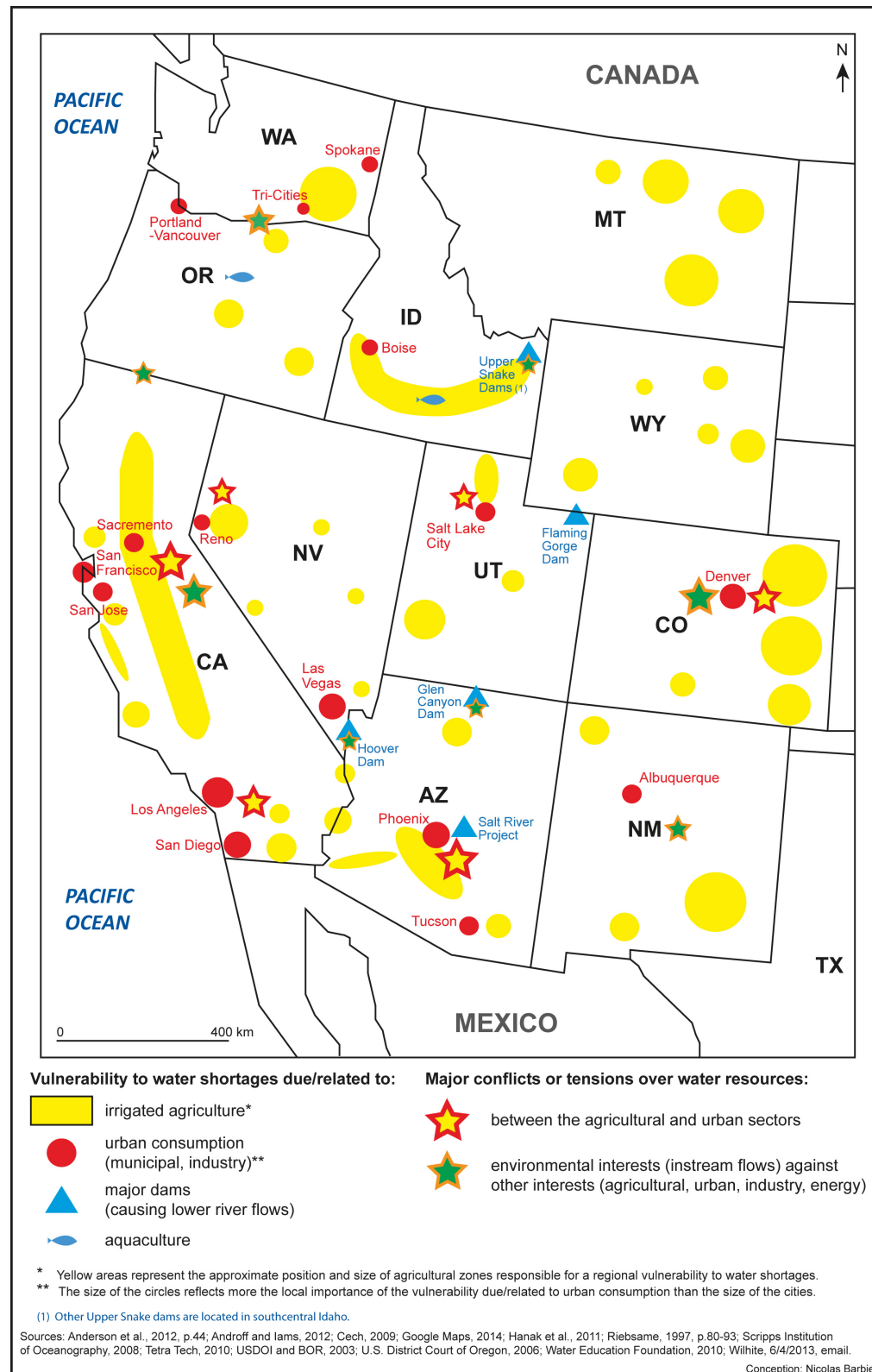


Source: Tetra Tech, 2010

- 18 The uneven geographic distribution of the risk of water shortages reflects the uneven spatial distribution of the factors of vulnerability.

## II/ The spatial distribution of vulnerability contingent upon climate, development, and the law

- 19 In the context of this chapter, the use of the word development has to be clarified: its spatial distribution varies mainly according to the spatially variable extent of land and water uses and population growth.

**Figure 3 - The sectoral and geographic distribution of vulnerability to water shortages**

Sources: Anderson *et al.* 2012, 44; Androff and Iams 2012; Cech 2009; Google Maps 2014; Hanak *et al.* 2011; Riebsame 1997, 80-93; Scripps Institution of Oceanography 2008; Tetra Tech 2010; USDOI and BOR 2003; U.S. District Court of Oregon 2006; Water Education Foundation 2010; Wilhite 6/4/2013, email)

20

Irrigated agriculture is the main factor of vulnerability in most areas, from the western Great Plains of Wyoming and Montana in the northeast to the dry lands of New Mexico and Arizona in the Southwest. In regions where the increasing demand for water in urban areas is associated with intensive agricultural use of water, conflicts or tensions have arisen (e.g., Arizona, California, Colorado or Nevada). Most mountainous regions where precipitation

is quite abundant (northern Idaho, western Montana, western Oregon and Washington) are generally not vulnerable. However, low river flows are issues of concern in some mountain ranges because they are detrimental to aquatic and riparian ecosystems (in northern Colorado or eastern California for instance). These ecosystems have been degraded due to insufficient flows or are increasingly vulnerable because of them. Irrigators keep drawing huge amounts of water in different mountain ranges. Locally, some dams and their reservoirs contribute to this ecological problem (e.g., the Hoover Dam in Arizona, Upper Snake Dams in Idaho). Conflicts or tensions between the different stakeholders (proponents of the conservation/ restoration of ecosystems, intensive irrigation, expanding suburbs or aquaculture) persist in various areas (Figure 3). Some of the solutions initiated by these protagonists to end or lessen these disputes are addressed in this study.

- 21 Elected officials and managers may have to act decisively and apply solutions during the forthcoming years to respond to consecutive years of drought and an emergency situation in the Southwest.

## 1/ Consecutive years of drought in the West and emergency in the Southwest<sup>15</sup>

- 22 According to the U.S. Geological Survey, “the word drought has various meanings”.

“To a farmer, it is a period of moisture deficiency that affects the crops under cultivation. To a meteorologist, it is a prolonged period when precipitation is less than normal. To a water manager, a drought is a deficiency in water supply that affects water availability and water quality. To a hydrologist, a drought is an extended period of decreased precipitation and streamflow” (USGS 2014 [c]).

- 23 Recently, the problem for farmers and municipalities has been the repetition of drought. Between 2000 and 2004, the American West had experienced its longest and widest drought since 1900. When it reached its peak in August 2002, it affected 87 percent of this region. Between 2003 and 2007, the warming of the American West was 0.7°C above global warming (Saunders *et al.* 2008, 2, 11). In 2011, a part of eastern New Mexico was hit by an exceptional drought: “through September of that year, statewide average precipitation was only 59 percent of normal” and generally less than 40 percent in southeastern New Mexico (U.S. Drought Monitor 2011). Between the spring and fall of 2012, a drought of varying intensity (from moderate to extreme) affected most of the American West (NOAA Fisheries Service 2012). In March 2014, most of California was affected by a drought ranging from severe to exceptional (U.S. Drought Monitor 2014). Brad Rippey, who works as a meteorologist for the U.S. Department of Agriculture, considers that drought fuels drought: it is the result of a “feedback loop associated with drought. That is to say, dry soils and drought-affected plants don’t release much moisture into the air, which leads to [less rain] when cold fronts pass through” (Freydin 2013). Between 2011 and May 2013, drought also spared vast areas in the wettest portion of the American West: northern Idaho, northwestern Montana, northern and western Oregon and Washington were essentially unaffected (NOAA Fisheries Service 2011; U.S. Drought Monitor 2014).

- 24 Even though most of the West is either arid or semi-arid, not many Westerners have built resilience in the face of drought vulnerability. Rather, communities and governments have favored a type of irrigated agriculture and urban growth that over time have increasingly fueled vulnerability. The region will probably face successive drought during the course of the 21<sup>st</sup> century. In these conditions, perhaps only the simultaneous involvement of farming communities, urban neighborhoods, industries, governments and the scientific community to save water can reduce the vulnerability to major water shortages in a significant manner. This collective resilience in the face of drought vulnerability would mean that society is able to cope with this problem efficiently. Over time, resilience should lead people to overcome vulnerability by finding long-term solutions. Global warming may force Westerners to become resilient through the adoption of a new behavior toward water resources.

- 25 In 2050, global warming might be moderate. Its future intensity is uncertain. But by then, even with a moderate global warming and in spite of huge reservoirs of dams (Mead, Powell), it is



estimated that the Colorado River may not meet the current level of water consumption most of the time. According to the National Academy of Sciences, States within the Colorado Basin should get ready for “costly, controversial and inevitable” compromises in terms of water uses (National Academy of Sciences 2007). The State of Arizona considers limiting growth and paying farmers in advance for a part of their water rights during years of drought. Tim Barnett and David Pierce (University of California in San Diego) expect “a major societal and economic disruption in the desert Southwest; something that will affect each of us living in the region” (Scripps Institution of Oceanography 2008).

- 26 Depletion of aquifers is one of the water issues faced by the population in the Colorado Basin and elsewhere. Farmers in southeastern Colorado and eastern New Mexico for example might soon have to give up a part of the irrigated lands because of aquifer drawdowns (Fiege 2009, 39-40; Job 2009, 12; Wilhite 6/4/2013, email). In the semi-arid portion of southern Colorado, the activity of some farmers is increasingly precarious. Overpumping from aquifers has caused the water table to drop and led commercial farmers to consider purchasing new surface water rights. As a consequence of this additional cost, they may have to stop farming on about 33,000 hectares (Finley 2012). Even the surface water rights may be threatened by insufficient spring runoff resulting from decreasing snowpack on the surrounding mountains. This snowpack fuels local rivers and irrigation ditches.
- 27 Snowpack is one of the major sources of renewal of water resources in federal lands. These resources are crucial for agricultural and urban areas across the West. They are vulnerable because of some recurrent dissimilar interests.

## 2/ Vulnerability of water resources on federal lands

- 28 Federal lands cover almost half the American West (Riebsame 1997, 58). In national forests (570,000 km<sup>2</sup> in the West), the U.S. Supreme Court decision in *United States versus New Mexico* (1978) has limited the scope of federal authority over water resources to the benefit of the States. The court ruled that States have authority to adjudicate “secondary” federal water rights in these forests. These rights include instream flows used to preserve ecosystems, wildlife, recreation and aesthetic features. An instream flow means “a specific rate of flow through a specific reach of stream” (Colorado Water Conservation Board 2010) set by a legally competent decision-maker. It is usually associated with a water right. Contrary to “primary” water rights, “secondary” water rights are not considered by law to be a top priority within these federal lands. The U.S. Forest Service (USFS) has defined “primary” rights for firefighting or administrative purposes for example. The amount of water dedicated to “primary” federal water rights in national forests is generally lesser than the amount devoted to “secondary” rights. In 1991, a Colorado State court ruling exemplified the potential jurisdiction of State courts over “secondary” federal water rights. The court ruled on instream flows of national forests located in northeastern Colorado. It favored the water supply of major cities like Denver and Boulder as well as irrigated lands over instream flow protection. Nevertheless, pursuant to the Organic Administration Act of 1897, the USFS keeps the power to secure favorable conditions of water flows. Due to the multiple-use principle applied in national forests, environmental conservation (including the maintenance of water flows), logging, mining, grazing and recreational activities are equally important. In national parks (58,000 km<sup>2</sup> in the West), “primary” federal water rights encompass instream flows because the U.S. Congress considers that it is essential to preserve natural processes in these areas. But overall, most federal instream flow water rights within federal lands are recognized as “secondary”. On U.S. Bureau of Land Management Lands (650,000 km<sup>2</sup> in the West), National Monuments and National Recreation Areas (much smaller than BLM lands), most water rights fall under the authority of States. On BLM lands, springs and water bodies are in theory subject to federal reserved water rights. But most of them are used for grazing or domestic purposes (Amos 2006, 1245; Gillilan and Brown 1997, 179-193; Riebsame 1997, 58-59).
- 29 There are both tensions and cooperation between federal agencies (e.g., BLM, USFS, National Park Service) and States about water resources management in federal lands. Agencies regularly apply State law mechanisms to manage these resources in a way that is consistent

with federal purposes. For instance, the State of Wyoming has permitted instream flows for the federally classified wild and scenic Clarks Fork River to move closer to a natural hydrograph. Still, States have often pressured federal agencies to seek water rights under State law and tried to prevent the implementation of the federal reserved water rights doctrine. The latter means that when the federal government reserves or acquires land “for particular purposes, there is an implied reservation of unappropriated water at the time necessary to achieve the purposes of the reservation”. Under the doctrine, the federal reservation of water (including its amount) does not fall within State law. When a federal purpose cannot be carried out under State law, the BLM and USFS can either apply this doctrine and deviate from State law or give up a part of this purpose. Three examples help clarify this issue. According to Colorado law, an instream flow should “preserve the natural environment to a reasonable degree,” which may not be sufficient to meet certain federal purposes. In Colorado, Idaho, Oregon and Washington, State law does not allow a federal agency to hold an instream flow water right and lets the State adjudicate federal claims. Even when a federal agency can hold this category of right, States can alter their water law or prioritize older non-federal water rights over federal rights during times of drought. States can do this after the issuance of the federal water right certificate (Amos 2006, 1244-1272). These problems between States and federal agencies play a role in the regional vulnerability to water shortages: the fate of immense water resources on federal lands is uncertain and excessive water uses could be allowed to the detriment of others.

30 Water resources concentrated on the federal lands of southern Idaho are coveted by the proponents of economic development and growth. Ongoing conflicts about these resources are not likely to stop.

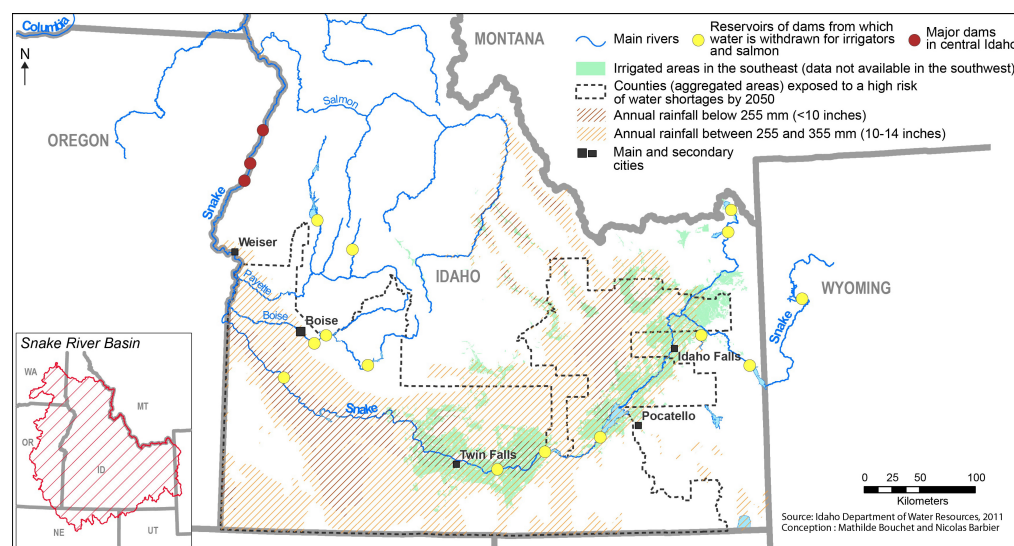
### 3/ Southern Idaho: conflicting priorities

31 Irrigated agriculture is an economic priority in southern Idaho. This area is representative of a sizeable portion of the West. In 2007, 97 percent of Idaho's 1.3 million hectares of irrigated lands were concentrated in thirty counties that constitute the southern half of this State (USDA 2007 [a]) (Figure 4). Potato, wheat, hay, sugar beet and barley are the State's five main crops. That year, the value of sold farm products raised on irrigated lands accounted for 81 percent of the value of all products raised in the agricultural lands of Idaho (\$5.7 billion) (USDA 2007 [b]). In order to remedy low average annual rainfall (200 to 400 millimeters), an average of 6,600 m<sup>3</sup> of irrigation water per acre and per year is used on Idaho irrigated lands. By comparison, the national average is 3,000 m<sup>3</sup> (USGS 2009, 24). The size of intensively irrigated lands is ill-suited to the climate of southern Idaho. In this region and in a decreasing order of volume by source of water, irrigation water withdrawals come from: the reservoirs of dams (fed by mountain streams and mostly snowmelt waters) including the American Falls, Anderson Ranch (Figure 5) and Palisades reservoirs; rivers and springs; groundwater (Falk 4/4/2011, email). Sprinklers (moving pivoted linear systems) are used on 65 percent of irrigated lands in Idaho. They do not waste as much water as flood irrigation<sup>16</sup> (35 percent of irrigated lands) does (USGS, 2009, p.24). However, a part of the excess water from flood irrigation recharges aquifers. From 1987 to 2009, the great aquifer of southeastern Idaho (Eastern Snake River Aquifer) decreased by 493 million m<sup>3</sup> per year (despite gains during some years). At least 123 billion m<sup>3</sup> can be tapped without difficulty from this aquifer. The growing use of sprinklers and a lesser use of rivers explain the drawdown of water levels in the aquifer. Moreover, river flows tend to dwindle due to snowpack declines in neighboring mountain ranges (Idaho Department of Environmental Quality 2006; McVay 4/14/2011, email).

32 A major dispute in southern Idaho is related to the water concentrated in the reservoirs of dams which are located in these mountain ranges. The levels of these reservoirs vary in part according to snowpack. This dispute has revolved around two connected issues: first, an allegation of violation of the 1973 Endangered Species Act (ESA, an act of Congress) that protects several species of salmon; second, local water rights. In this case, a federal court can change water rights because the ESA (a federal statute) is involved. Starting in 2004, federal judge James Redden was in charge of the *American Rivers v. NOAA Fisheries Service et al.* lawsuit. Since then, environmental and fishing groups (e.g., American Rivers, the Federation

of Fishermen's Associations, National Wildlife Federation) have been opposed to federal agencies (the NOAA Fisheries Service in charge of managing and conserving salmon and its habitat; the BOR), the Governor of Idaho and irrigation districts. In 2006, in accordance with the authority in theory conferred upon him by the ESA, judge Redden suggested the possibility of forcing holders of irrigation rights (irrigators) to lease a part of their rights in order to protect salmon. These irrigators draw water from high elevation reservoirs in southern Idaho which is also part of the Upper Snake River Basin. A part of this water is released every year to facilitate salmon migration in the lower Snake River (Figure 4). Before James Redden issued his opinion, the irrigators had agreed to lease a certain amount of water to help salmon. But the volume they agreed upon was lower than what was considered by judge Redden. The Governor of Idaho and a Congressman from this State adamantly opposed Redden's opinion. As a result, the judge renounced the idea to force irrigators to lease more water for salmon (Crapo 2006; Wasden 2004). In other words, some of the most prominent representatives of the State of Idaho have successfully opposed interference by the federal judicial branch in their system of water resource management. Although the conflict and lawsuit are not yet over, the judge that succeeded James Redden in 2011 (Michael Simon) has not forced the irrigators to release more water than the amount they agreed upon. As a consequence, salmon remain vulnerable to insufficient river flows in the lower Snake, which can kill or harm some of them and impact the fishing industry. Four percent of southern Idaho's irrigated area could be threatened if the judge decided to order an annual release of 1.24 billion m<sup>3</sup> of water from the different reservoirs (more than twice the amount agreed upon by irrigators). According to the NOAA Fisheries Service, this amount is necessary to avoid jeopardizing salmon in the lower Snake (U.S. District Court of Oregon 2006).

**Figure 4 - The domination of agricultural interests over ecological interests in southern Idaho**



Source: Idaho Department of Water Resources, 2011

- 33 Across the West, farmers and irrigators may have to sell or lease a much greater amount of water and give up a much larger irrigated area in order to restore an agriculture that would be consistent with climate and demographic projections.

### III/ Incomplete correlation between climate and demographic projections and regional priorities

- 34 According to Olen Matthews (director of the geography department at the University of New Mexico), State programs for the long-term protection of water resources are either nonexistent or inadequate in most of the West (Matthews 6/4/2013, email). Some are currently in development.

## 1/ Real changes in agricultural practices?

- 35 Researchers like Sally Mckenzie (University of Nebraska) work on epigenetics, which means the regulation of the gene activity of plants without altering their genetic heritage. Still in its experimental stage, this work is intended to raise the resistance of cultivated plants to water stress. For instance, researchers simulate the illusion of the need for water in plants. The latter grow more rapidly and better adapt to climate change (National Public Radio 2013).
- 36 A lot of other projects are beyond the experimental stage and have been applied on the ground for some time. In order to save water, Robert Evans (project manager at the U.S. Department of Agriculture [USDA] Research Service) promotes the use of in-field sensing stations integrated into irrigation sprinkler systems. Wireless-sensors detect the level of humidity and temperature in the soil. They relay the information to the computerized irrigation sprinkler system also equipped with a tiny meteorological weather station. Sensors enable farmers to irrigate their crops with the right amount of water at appropriate times. Compared with a similar system without sensors, Robert Evans considers that it generally reduces the amount of water used by 5 to 10 percent. The reduction can reach 50 percent if the farmers agree to decrease their yields by 10 to 30 percent while ensuring an optimal moisture management (Evans 4/13/2011, email; USDA-ASRU 2007).
- 37 According to USDA agronomist David Nielson, some farmers only irrigate when it is indispensable. By doing so, they also quit trying to maximize their yields. Furthermore, a lot of them have adopted no-till farming, hence a better water-holding capacity of the soil (National Public Radio 2013).
- 38 For its part, the BOR focuses a lot on irrigation systems. In 2011, it spent a total of 24 million dollars in the American West so as to save 127 million m<sup>3</sup> of water annually. In late 2012, the BOR and USDOJ were “on track to achieve the goal” of more than 900 million m<sup>3</sup> of water savings per year after four years of effort (2010-2013) in the West (including Texas). Although it represents a substantial amount of water, it is minor in comparison with the volume of water necessary for irrigated lands across the West. 900 million m<sup>3</sup> could irrigate about 550 km<sup>2</sup> for a year in southern Idaho. Some projects give a glimpse of the kind of work these federal entities are doing to save water: fixing leaks in irrigation ditches; converting open ditches to pipelines; installing flow control systems in the network of irrigation canals as well as water distribution systems more accurate in terms of volumes of distribution (USDOJ 2012; USDOJ et BOR 2011[a]; USDOJ et BOR 2011 [b], 4).
- 39 In the same vein and within the framework of the 2008-2012 Federal Farm Bill,<sup>17</sup> the USDA funded a series of water conservation projects. In Idaho for instance, four projects cost 6.9 million dollars: the conversion of two flood irrigation systems into irrigation sprinkler systems; a local replacement of groundwater as supply source by surface water; plugging leaks in a canal. The USDA also assists farmers when they want to convert their irrigated farm into dryland farming, but these initiatives are rare (USDA 2009).
- 40 Overall, federal projects and incentives to save water are not intended to profoundly change a considerable part of intensive irrigated agriculture. But federal entities do seize diverse opportunities to save water. So far though, their impacts have been limited.
- 41 The same can be said of water-saving methods like drip irrigation<sup>18</sup> (only 2,000 hectares in southern Idaho for instance [USGS 2009, 24]) or double digging<sup>19</sup> (University of California Santa Cruz 2010). Small and truck farmers apply them in a tiny minority of the West's irrigated lands. They are going against the maintenance of intensive farming still preferred by U.S. Farm Bills. The impact of this dominant agriculture on river flows is serious.

## 2/ Slow progress of instream flows to protect aquatic and riparian ecosystems

- 42 Insofar as this study is about vulnerability to water shortages, we address the vulnerability of aquatic and riparian ecosystems to the reduction of river flows. It is both an ecological and economic problem which notably affects trout and salmon species and popular whitewater sports.

43 “Increases in water temperatures” is among some of the most significant projected ecological impacts of climate change related to declining river flows in the West. These increases are expected to “stress fisheries that are sensitive to a warming aquatic habitat,” [...] and cause decline in “amphibian populations, and effects on pests and pathogens in ecosystems” (USDOI and BOR 2011 [c], 71- 87). According to a 2011 report by the USDOI, the impact of both global warming and water uses are leading to an increasingly high risk of declining river flows: river flows in the Colorado (westcentral American West; Southwest), Columbia (Northwest), Klamath (southern Oregon, northern California), Missouri (eastern Colorado, Montana and Wyoming), Rio Grande (Southwest) and Sacramento-San Joaquin (northern California) river basins are expected to drop by 8 to 20 percent. The USDOI predicts repercussions on water supply that is already in jeopardy in some regions. In 2011, Secretary of Interior Ken Salazar highlighted the urgent necessity to devise an action plan to address this risk. His department announced that it would predominantly focus on reducing water used by the energy sector (Zabarenko 2011). As an example, in late 2012 the USDOI planned “multiple high flow experimental releases” from Glen Canyon Dam on the Colorado River to “rebuild and conserve sandbars, beaches, and associated backwater habitats that have been lost or depleted since the dam’s construction and operation” (Androff and Iams 2012). The goal of this work is the ecological restoration of ecosystems and their functioning that had been either disrupted or destroyed.

44 To avoid having to restore ecosystems, States protect threatened rivers. Colorado and California are probably the most advanced States as far as instream flow protection is concerned (Wilhite 6/4/2013, email). In 2010, the California Environmental Protection Agency (CEPA) established principles for the protection of river ecosystems in coastal regions. It ruled that water diversions must not endanger instream flows necessary for: fish passage and spawning grounds; a network of channels well suited to the needs of fish within riverbeds. Moreover, new dams must not be harmful to fish and their habitat (CEPA 2010, 2-3). In 2013 in Colorado, a cooperative work based on a State program for the maintenance of instream flows brought together groups of environmentalists, fishermen and whitewater adventurers along with managers of water resources, some counties and private landowners (Colorado Water Conservation Board). Thanks to their efforts, a State court was able to establish instream flows that are supposed to protect ecosystems (including trout habitat) on 120 kilometers of the Upper Colorado River (Berwyn 2013).

In order to save more water resources, managers also work on the consumption of households in cities and groundwater withdrawals.

### 3/ Local reduction of groundwater withdrawals and household consumption

45 Various projects are underway to reduce groundwater withdrawals and recharge aquifers. A brief summary of two projects help understand the local efforts made and the type of work involved. In the northwestern suburbs of Phoenix (Arizona), a \$4.5 million project involving the municipality of Surprise and the BOR will result in saving about five million m<sup>3</sup> of water per year by building recharge wells and pipelines that will recharge the local aquifer. In central California south of Fresno, more than \$1.8 million are spent in the construction of a levee and check structure with automated gates that will make the use of storm and flood water possible in a local recharge basin, thus increasing groundwater recharge. A local water conservation district (Kaweah Delta) and the BOR cooperate to carry out this project that should lead to a better management of about 48 million m<sup>3</sup> of water each year (USDOI and BOR 2011 [b]).

46 Other projects aim at reducing household consumption of water in cities. These efforts will not considerably reduce vulnerability to water shortages in the West in general because the withdrawals for irrigated agriculture are much larger than for household consumption. However, they are a part of the solution to diminish this vulnerability in some cities and metropolitan areas. In Goleta on the southern Californian coast for example, “a water efficiency program emphasized plumbing retrofits” (high efficiency toilets and showerheads) and “increased rates”. It “resulted in a 50 percent drop in per capita water use”. In southern



California again (Orange County, Greater Los Angeles Area), treatment technologies and a \$481 million water recycling facility (producing 265 million liters of water per day) were used to purify wastewater. The community agreed to let the water “percolate into the groundwater basin for later use as potable water” (Natural Resources Defense Council 2012, 18). A lot of these projects are very recent. It is their multiplication over the forthcoming decades that may attenuate the regional vulnerability.

### Figure 5 - Water uses and savings in the American West

Source: Golfers West, 2014.



The Ritz-Carlton golf course north of Tucson, Arizona in a desert climate.

Source: Betsy Malloy, 2009.



An irrigation canal near Palm Springs in southern California.

Source: Riverwild, 2009.



The Anderson Ranch Dam in southern Idaho provides irrigation water and hydroelectric power.

Source: Synergy Sotheby's International Realty, 2012.



A mansion and its private water park for sale in Boulder City (Mojave Desert, Nevada).

Source: Kestrel Consulting Inc, 2014.



A \$103 million project (including \$20 million from the U.S. Bureau of Reclamation) in Oxnard, California is expected to result in 8.9 million m<sup>3</sup> of recycled water per year, through wastewater reuse.

Source: USDOl, 2012.



The Deschutes River Conservancy and Three Sisters Irrigation District in Oregon have participated in the installation of pipes that replace an irrigation canal from which water previously seeped into the soil. 925,000 m<sup>3</sup> of water are expected to be saved annually.

Sources: Golfers West 2014; Malloy 2009; Riverwild 2009; Synergy Sotheby's Realty 2012; Kestrel Consulting 2014; USDOl 2012)

## Conclusion

47 The agricultural sector dependent upon irrigation has been controlling most water resources by means of water rights since the end of the conquest of the West. So far, State authorities have been exercising their sovereignty on most water resources while protecting the interests of intensive irrigated agriculture. This agricultural sector holds primary responsibility for the map of the vulnerability to water shortages within most of the West. In general, urban growth (Phoenix in Arizona, Denver in Colorado, Las Vegas in Nevada, etc.) and hydroelectric power (for example the four dams on the Colorado River between southern Nevada and California) have intensified water stress to the detriment of aquatic and riparian ecosystems. Public entities in cities and metropolitan areas usually acquire or lease high-priced water rights from representatives of the agricultural sector. The human impacts on water resources are further heightened by the effects of global warming. Together they are leading to a high risk of water shortages on hundreds of thousands of square kilometers by 2050. Very broad in the Southwest (more than half of its counties), this risk is more localized elsewhere (western Utah, eastern Montana and Colorado, southern Idaho, etc.). In numerous areas, this risk results from a predicted combination of: a decrease in available precipitation; the maintenance of intensive irrigated agriculture; growing urban water consumption. Apart from local and small areas, solutions that significantly reduce agricultural water uses while protecting reasonable instream flows are developing too slowly to reverse the situation. Solutions based on genetic manipulations of cultivated plants could soon spread in the West. Law professor Eric Freyfogle (Swanlund Chair at the University of Illinois) suggests a legal evolution: to authorize State courts to temporarily suspend environmentally harmful water rights so that courts do not have the inappropriate forfeiture of water rights as the only available legal solution; to extend the courts' power to restrict existing water rights (Freyfogle 2003, 231-234). Vulnerability to water shortages could also be lessened if a hierarchy of priorities was applied: 1) absolute priority maintained for domestic, hospital and sanitation uses of water; 2) second, agricultural uses well suited to local (and changing) climate conditions as well as sustainable uses by businesses, industries and public institutions (exclusion of superfluous uses); 3) the protection of instream flows that would secure the preservation of aquatic ecosystems would come third; 4) finally, because it threatens projects of sustainable development when it is widespread, intensive irrigated agriculture would only come fourth. This hierarchy surmises that agricultural subsidies would favor the adoption of water saving practices. Such an evolution remains unlikely in the arid and semi-arid American West today. However, examples in Colorado or California suggest a possible evolution toward this kind of solutions. In a growing number of territories (small river basins, counties...), the majority of the population and elected officials could someday support them.

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FALK, John. Email (john.falk@idwr.idaho.gov) received on April 4, 2011. Director of the office of dam safety for the Idaho Department of Water Resources (IDWR).

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MATTHEWS, Olen. Email (opmatt@unm.edu) received on June 4, 2013. Head of the geography department at the University of New Mexico.

WILHITE, Donald. Email (dwilHITE2@unl.edu) received on June 4, 2013. Professor at the University of Nebraska-Lincoln (School of Natural Resources) and director of the National Drought Mitigation Center.

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## Notes

1 The eleven States of the American West are Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington and Wyoming.

2 The definition of vulnerability is provided by the Organisation for Economic Co-operation and Development (OECD 2001).

3 The U.S. Bureau of Reclamation manages a part of the water supply (notably irrigation) and hydro power in the American West.

4 In March 2014, the most recent data on water uses in States dated from 2005. 2010 data will not be available before late 2014 (USGS 2014).

5 I added up the irrigated acreage of the eleven States of the American West.

6 "Public-supply water is delivered to users for domestic, commercial and industrial purposes. It is also "used for public services and system losses" (USGS 2009, 16).

7 The article from which these statistics are drawn adds Texas in the American West.

8 Agriculture-to-urban lease of a water right: a lessor from the agricultural sector leases water to an urban entity for an urban use.

9 One acre-foot=1,233 cubic meters; one acre=0.4 hectare.

10 Agriculture-to-agriculture lease of a water right: a lessor from the agricultural sector leases water to another member of this sector for an agricultural use.

11 Professor at: the Bren School of Environmental Science and Management; the Department of Economics at the University of California in Santa Barbara.

12 2000-2010 population growth in western States: +25 percent in Arizona; +10 percent in California; +17 percent in Colorado; +21 percent in Idaho; +12 percent in Oregon; +24 percent in Utah; +21 percent in Texas; +14 percent in Washington and Wyoming (U.S. Census Bureau 2013).

13 Public uses: municipal, domestic and public institutions; do not include commercial and industrial uses.

14 Per capita water use: volume of water withdrawn for public uses / [divided by] the total population.

15 The Southwest encompasses Arizona and New Mexico. Some authors add southern California and the far south of Nevada to this region.

16 Flood irrigation: "water is pumped or brought to the fields" flowing in pipes or ditches; it "is allowed to flow along the ground among the crops" (USGS 2014 [b]).

17 "The farm bill is an omnibus, multi-year piece of authorizing legislation that governs an array of agricultural and food programs" (Congressional Research Service 2013).

18 Drip irrigation: water slowly drips toward the roots. It either flows on the soil surface or directly irrigates the rhizosphere through a network of pipes.

19 Double digging: the soil is broken up about sixty centimeters deep. Compost is applied on it. The soil becomes well-aerated and water seeps down easily. The need for watering is lowered. Deeper root development improves nutrient intake and plant density increases. It results in better yields.

### ***Pour citer cet article***

#### Référence électronique

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### ***Résumés***

#### **Vulnérabilité à la pénurie en eau dans l'Ouest américain aride et semi-aride à l'aube du XXI<sup>ème</sup> siècle**

Les études scientifiques convergent pour démontrer la vulnérabilité hydrique croissante de l'Ouest américain aride et semi-aride. Au cours des cinquante prochaines années, il est fort probable qu'au moins une partie de la population régionale soit confrontée à un risque de pénuries en eau remettant en question la durabilité de l'agriculture irriguée et de la croissance urbaine dans de vastes zones. Cet article propose une explication du phénomène et de sa variabilité spatiale au moyen d'une analyse d'études existantes, du droit, de discours de spécialistes et des solutions envisagées.

Scientific studies agree to stress the growing risk of water shortages in the arid and semi-arid American West. Over the next fifty years, at least part of the local population will likely face water shortages which will call into question the sustainability of irrigated agriculture and urban growth in large areas. This article will explain this phenomenon and its spatial variability by analyzing existing studies, U.S law, the writings of experts and the potential solutions they have come up with.

#### **Vulnerabilidad ante la penuria de agua en el Oeste estadounidense árido y semiárido a inicios del siglo XXI**

Los estudios científicos convergen para demostrar la creciente vulnerabilidad hídrica en el Oeste estadounidense árido y semiárido. Durante los cincuenta próximos años, es muy probable que al menos una parte de la población regional se vea enfrentada a un riesgo de penuria de agua y que ello cuestione la durabilidad de la agricultura irrigada y el crecimiento urbano en amplias zonas. Este artículo propone una explicación del fenómeno y de su variabilidad espacial por medio del análisis de estudios ya existentes, del derecho, de discursos de especialistas y de probables soluciones.

#### **Vulnerabilidade à Penúria de Água no Oeste Americano Árido e Semi-árido no Limiar do Século XXI**

Os estudos científicos convergem no sentido de demonstrar a vulnerabilidade hídrica crescente do Oeste americano árido e semi-árido. Durante dos próximos cinquenta anos, é altamente provável que uma parte pelo menos da população regional seja confrontada a um risco de penúria de água, pondo em questão a durabilidade da agricultura irrigada e do crescimento urbano em vastas zonas. Este artigo propõe uma explicação do fenômeno e de sua variabilidade

espacial por meio de uma análise dos estudos existentes, do direito, de discursos de especialistas e das soluções imaginadas.

***Entrées d'index***

***Mots-clés*** : Ouest américain, vulnérabilité hydrique, agriculture irriguée, croissance urbaine, droit américain

***Keywords*** : American West, water shortages, vulnerabilities, irrigated agriculture, urban growth, U.S. law

***Palabras claves*** : Oeste estadounidense, vulnerabilidad hídrica, agricultura irrigada, crecimiento urbano, derecho estadounidense

***Palavras chaves*** : Oeste americano, vulnerabilidade hídrica, agricultura irrigada, crescimento urbano, direito americano

## Note from the author about this update

I wrapped up this article just before the [estimated use of water in the United States in 2010](#) was released by the U.S. Geological Survey (November 2014). So I had to use the 2005 USGS data in my article. [In the following paragraph, I added 2010 data \(highlighted in blue\).](#)

### 1/ 3/ Irrigated agriculture: the dominant factor of vulnerability compounded by others

[...]

In 2005, more than 102,000 km<sup>2</sup> (10.2 million hectares) were irrigated within the eleven western States including 37,000 km<sup>2</sup> in California, 14,000 in Idaho and 12,000 in Colorado (USGS, 2009, p.24). [In 2010, 105,000 km<sup>2</sup> were irrigated within the eleven western States.](#) The part of agriculture in total water withdrawals dominates all other water uses. In 2005, in nine States out of eleven, irrigation used between 74 percent (California) and 95 percent (Montana) of the total fresh water withdrawals (63 percent in Nevada and Washington). [In 2010, in nine States out of eleven, irrigation used between 74 percent \(California\) and 94 percent \(Montana and Wyoming\) of the total fresh water withdrawals \(60 percent in Nevada; 63 percent in Washington\)<sup>1</sup>.](#) It greatly exceeds the percentage of public supply (for domestic, commercial, industrial and public services purposes) which comes second in most States (e.g. in 2005/[2010](#): 28/[22](#) percent in Nevada; 19/[20](#) percent in Arizona; 9/[9](#) percent in New Mexico). In 2005/[2010](#), aquaculture was second in Idaho (13/[16](#) percent) and Oregon (9/[11](#) percent). In most States ([except in Montana in 2010](#)), it should be noted that more fresh water is withdrawn for public supply than thermoelectric power (e.g. in 2005/[2010](#): 8/[0.8](#) percent withdrawn for thermoelectric power in Washington; 1/[0.7](#) percent in Colorado; 1/[2](#) percent Montana). [...]

#### *Source:*

USGS. "Estimated Use of Water in the United States in 2010". Circular 1405 (2014) [Retrieved on May 13, 2015] <http://pubs.usgs.gov/circ/1405/pdf/circ1405.pdf>

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<sup>1</sup> In 2010, there was no saline water withdrawal in Arizona, Idaho, New Mexico and Oregon, and almost none (less than 0.5 percent of total water withdrawals) in Colorado, Montana, Nevada and Washington. That year, saline water withdrawals accounted for 18 percent of total water withdrawals in California (mostly used for thermoelectric power), 7 percent in Utah and 1.5 percent in Wyoming.